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BUREAU OF MINES

H. FOSTER BAIN, DIRECTOR

THE UNIVERSAL AND THE FIREMAN'S GAS MASKS

BY

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CONTENTS.

	Page.
Introduction	1
Description of gas masks	2
Universal gas mask	2
Absorbents used	3
Fireman's gas mask	5
Tests of the masks	7
Machine tests	7
Tests on men	10
Limitations of universal gas masks	11
Summary and conclusions	13
Appendix	15
Standard test requirements for gas masks	15
Color and markings	15
Materials	16
Design and construction	16
Face-piece test	17
Resistance to flow of air	17
Canister tests	17
Type A, acid gases	17
Type B, organic vapors	18
Type C, ammonia	18
Type D, carbon monoxide	18
Type E, smoke, dust, and mist filters	19
Type F, other special individual gases	20
Types AB, AC, etc., special combinations for different types of gases, as above	20
Type N, for protection in air against all gases, vapors, and smokes	20
Chemical stability	21
High rates of breathing and maximum concentration	21
Approval for higher concentration	22
Changing of detail of tests	22
Publications on gas masks and breathing apparatus	22

ILLUSTRATIONS

PLATE	I. Universal gas mask	2
	II. Firemen's gas mask	3
FIGURE	1. Details of the universal canister	4
	2. Details of the fireman's canister	6
	3. Graphs showing life of canisters against various gases	7
	4. Graphs showing life of canisters against carbon monoxide at room temperature	9
	5. Graphs showing life of canisters against carbon monoxide at freezing temperature	9
	6. Graph from test of a universal canister against chlorine, sulphur dioxide, ammonia, carbon tetrachloride, and carbon monoxide	11

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THE UNIVERSAL AND THE FIREMAN'S GAS MASKS.

By S. H. Katz, J. J. Bloomfield, and A. C. Fieldner.

INTRODUCTION.

The Army gas mask as developed during the war gave protection against all the poisonous gases, vapors, and smokes encountered on the field of battle. But when, after the war, Army-type gas masks were advocated for use in metallurgical, chemical, and other industries where noxious gases or fumes occur, the Bureau of Mines immediately pointed out that the masks give no protection against ammonia gas used in refrigerating plants, or against carbon monoxide, a constituent of blast-furnace gas, producer gas, water gas, and coal gas. Carbon monoxide is formed by the incomplete combustion of carbonaceous matter and is a constituent of the gases from certain explosives. Recently, special gas masks having canisters containing absorbents designed for protection against ammonia or from carbon monoxide have been developed, but these afford little or no protection against other gases.

To combine efficiently in one canister the absorbents for all noxious gases is difficult because the absorbents for certain gases are best when moist, whereas an absorbent or catalyst for carbon monoxide can be used only when perfectly dry. Hence it becomes necessary to use dry absorbents for the other gases. After an extended series of experiments and tests the following dry, granular absorbents, arranged in order of the passage of air through the canister from bottom to top, were used for the "Universal" gas mask:

1. Activated nut charcoal.
2. Filter of cotton wool.
3. Caustic soda impregnated on pumice.
4. Filter of cotton wool.
5. Fused calcium chloride.
6. "Hopcalite," a carbon monoxide catalyst which causes oxidation of carbon monoxide to carbon dioxide.
7. Silica gel.
8. Filter of cotton wool.

A "fireman's" canister has also been developed, which is similar to the "universal" canister, but is smaller and lighter, thus making

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it more convenient to wear by city firemen. The life of this canister is shorter than the universal, but is adequate for use in the dilute concentrations usually encountered by firemen.

The universal and the fireman's gas masks may be worn in air containing small quantities of any noxious gas. An abundance of air is necessary, because the gas mask does not furnish the wearer with any of the oxygen necessary for life. An atmosphere in which a safety-lamp flame goes out must never be entered by a man wearing a gas mask. Oxygen breathing apparatus or air helmets only can be used in such places.

Most noxious gases may be detected by their odor or taste when they penetrate a canister, either because of its being exhausted or of its activity being insufficient to absorb a high concentration, so that one has time to escape from a dangerous atmosphere before he has breathed enough of the gas to cause injury. Carbon monoxide, however, has no taste nor odor; a man who breathes it may not be aware of its presence until he becomes greatly weakened or nauseated; he may lose consciousness without receiving any warning. Because of the danger from using an exhausted canister, a limit of six hours' use is put upon the universal and four hours' on the fireman's canisters.

In cool or cold weather the canisters should be worn under a coat because when warm they are more active against carbon monoxide than when they are cold.

Masks of the universal type are useful for emergency purposes around chemical plants or the like in which many different gases or vapors may be met. They are especially adapted to the work of city fire fighters, who encounter all kinds of poisonous gases. However, gas masks should not be used in mines for rescue and recovery purposes after explosions, because at such times the mine atmosphere is apt to lack oxygen. Self-contained oxygen breathing apparatus which carry supplies of compressed oxygen are needed for mine rescue work. When the atmosphere contains enough oxygen to support a lamp flame the universal or the fireman's gas mask will give protection against most gaseous hazards.

DESCRIPTION OF GAS MASKS.

UNIVERSAL GAS MASK.

Plate I shows the universal gas mask, which weighs about 8½ pounds, complete. A strap around the neck of the wearer, this strap connecting by snaps to metal loops, supports the canister, and a similar strap around the body steadies the canister against the chest.

The face piece is of the Tissot type, forming an air pocket over the face and allowing breathing through the nose; the wearer may talk

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UNIVERSAL GAS MASK.

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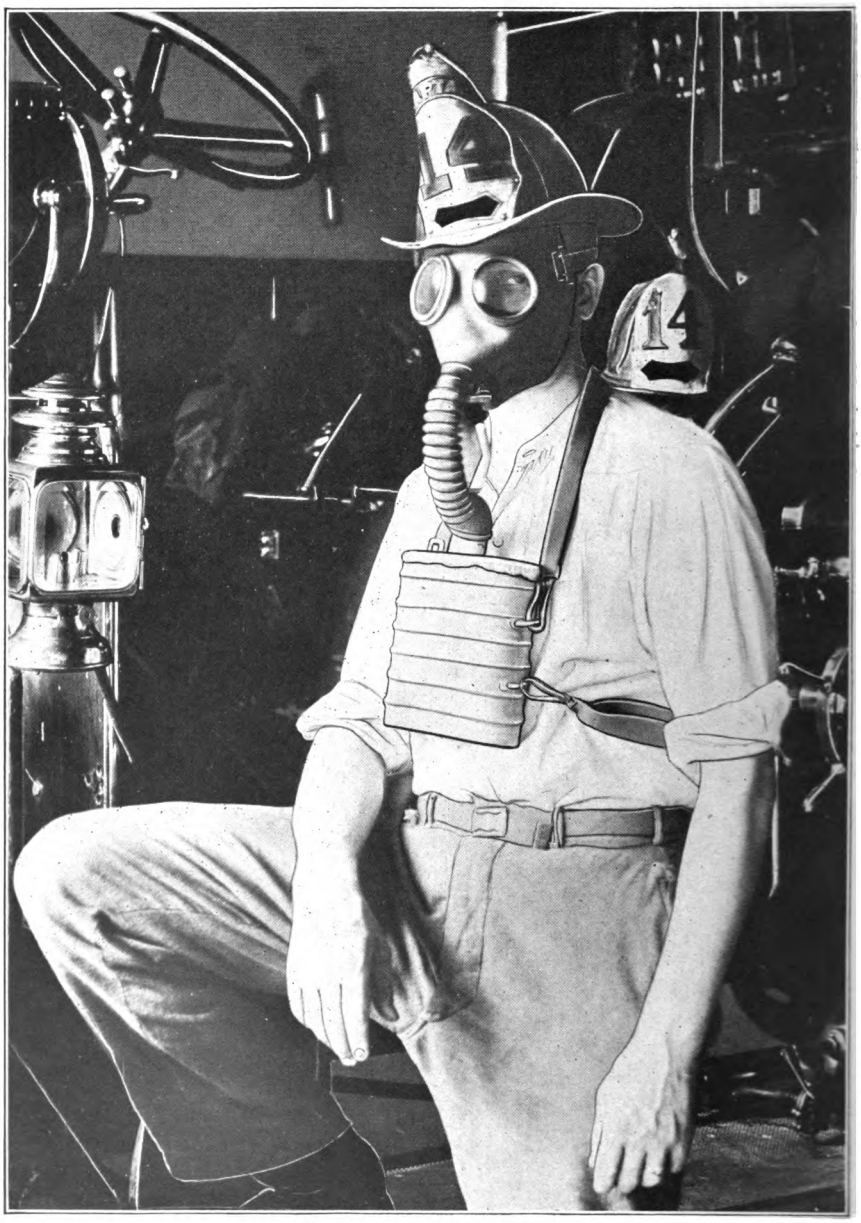

FIREMAN'S GAS MASK.

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as usual. Exhaled air passes through a flutter valve that allows outward flow only. A corrugated, noncollapsible but flexible rubber tube connects the face piece with the canister.

Figure 1 shows details of the canister, which measures $2\frac{3}{4}$ by $8\frac{1}{4}$ by $8\frac{5}{8}$ inches high and weighs about 7 pounds. Inspired air enters the canister at the bottom through a check valve. A dome of wire screen supports the granular absorbents and permits even distribution of the air through them. These absorbents, in 8 to 20 mesh sizes, are arranged as follows in order of their position, from bottom upward:

ABSORBENTS USED.

Dry, activated charcoal, 700 c. c. The charcoal absorbs organic vapors, which include alcohol, aniline, benzene, carbon bisulphide, carbon tetrachloride, ether, toluene, and the like. On the charcoal is a filter of cotton wool about one-fourth inch thick held between two light wire screens; this filters out suspensoids, including smokes, mists, and dusts, small particles of solid or liquid matter carried by the air.

Caustic soda fused on granular pumice stone, 300 c. c. Caustic pumice absorbs acid gases such as carbon dioxide, chlorine, formic acid, hydrogen cyanide, muriatic acid gas, oxides of nitrogen, sulphur dioxide, and gases of like chemical properties; caustic pumice also extracts water vapor from the air, thus preventing moisture from contaminating and inhibiting the hopcalite.

On the soda-pumice layer is another cotton-wool filter like the one beneath.

Fused calcium chloride, 400 c. c. Calcium chloride removes any moisture that may pass the caustic pumice.

Above the calcium chloride is a separator of wire screen.

Hopcalite[1], *500 c. c.* Hopcalite is a mixture of oxides of manganese, copper, and sometimes silver and cobalt, made into granules; it acts catalytically on carbon monoxide in air, causing the monoxide to take up oxygen and change to the dioxide. Air containing 2 or 3 per cent of the latter may be breathed without harm, whereas 0.04 per cent carbon monoxide may cause *illness or headache if breathed for more than one hour.*[2] Larger proportions (0.2 to 0.5 per cent) can quickly cause unconsciousness and death. As carbon monoxide is tasteless and odorless, its presence can not be detected by the senses. The life of a canister exposed to this gas is limited by the active life

[1] Lamb, A. B., Bray, W. C., and Frazer, J. C. W., The removal of carbon monoxide from air: Jour. Ind. and Eng. Chem., vol. 12, March, 1920, pp. 213–21.

[2] Henderson, Y., Hazzard, H. W., Teague, M. C., Prince, A. L., and Wunderlich, R. M., Physiological effects of automobile exhaust gas and standards of ventilation for brief exposures: Jour. Ind. Hyg., vol. 3, Aug., 1921, pp. 78–92; Sept., pp. 137–146.

Henderson, Y., How much gas can you breathe? Pop. Sci. Monthly, vol. 97, August, 1920, pp. 19–22.

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of the hopcalite, the latter failing as soon as moisture penetrates it, regardless of whether carbon monoxide is present or not. Tests have

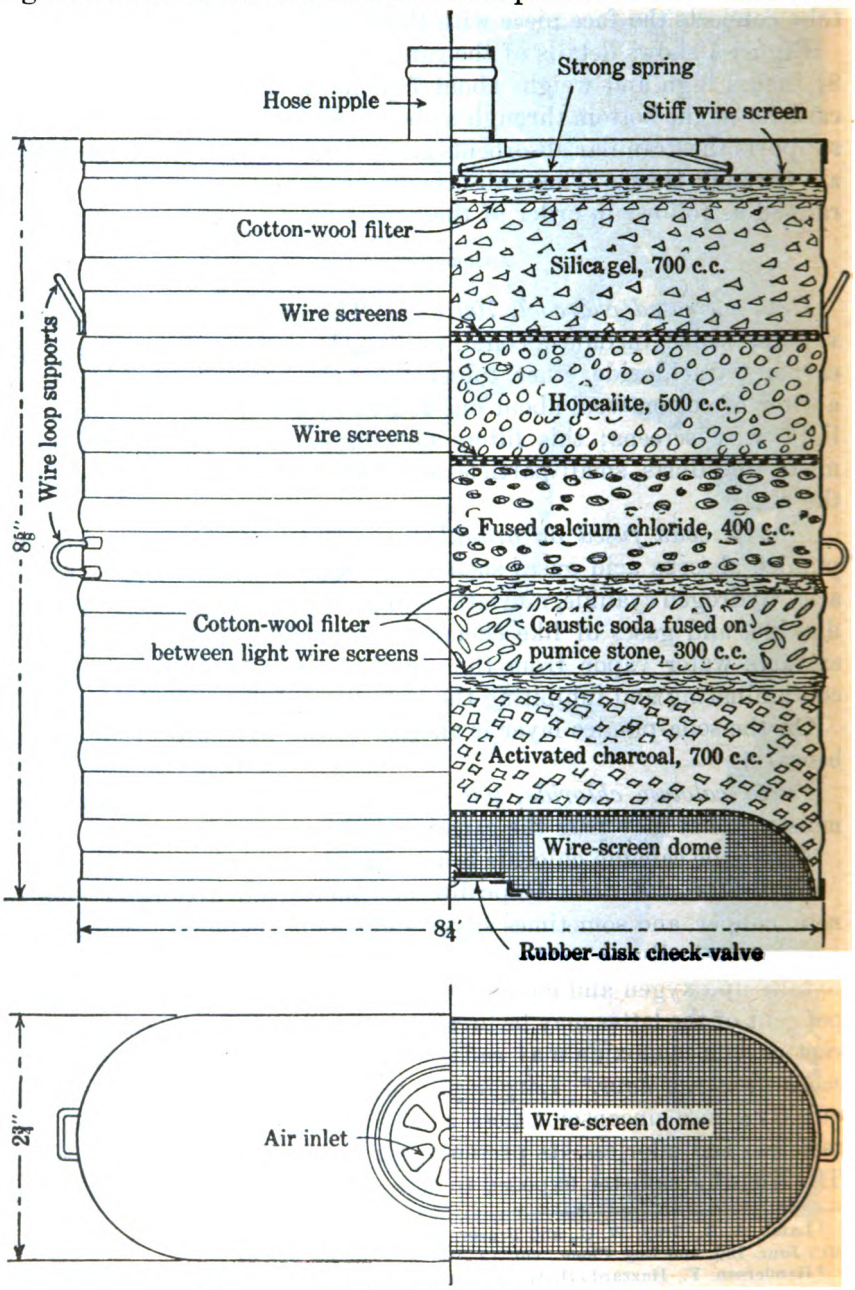

FIGURE 1.—Details of the universal canister.

showed the universal canister gives 14 hours' service at room temperature against carbon monoxide, but it can not be used that long be-

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cause of the inability of the wearer to know when carbon monoxide finally penetrates. For this reason the time of usage has been arbitrarily set at 6 hours, thus giving a large factor of safety. In addition to its catalytic action on carbon monoxide, hopcalite has some absorbent capacity for other gases.

Above the hopcalite is a separator of wire screen.

Silica gel, 700 c. c. Silica gel is a granular material, made by mixing water glass and muriatic acid, that absorbs organic vapors, approaching charcoal in that respect; it also absorbs ammonia, and is used in the canister for this purpose. The gel also serves as a guard to prevent moisture reaching the hopcalite from above.

Lastly comes a third filter of cotton wool which is placed between wire screens, the upper being very stiff. Springs bearing on lugs at the top of the can press on the top screen and hold all materials firmly in place. Between the top screen and the lid is a small vacant space.

Although the universal canister is larger than others, it is worn comfortably and interferes but slightly with the wearer's movements.

FIREMAN'S GAS MASK.

The fireman's gas mask, shown in Plate II (canister details in Figure 2) has the same style of face piece and canister support as the universal, but is smaller and lighter. The canister weighs 4 pounds as compared with 7 pounds for the universal, and the complete mask about 5½, as compared with 8½ pounds. The absorbents used in each are identical and are arranged in the same order except that the fireman's canister has only two cotton-wool filters. From bottom to top the absorbents in the fireman's canister are as follows:

Activated charcoal, 150 c. c.
Filter of cotton wool between light wire screens, one-fourth inch thick.
Caustic soda on pumice, 200 c. c.
Wire-screen separator.
Fused calcium chloride, 250 c. c.
Wire-screen separator.
Hopcalite, 400 c. c.
Wire-screen separator.
Silica gel, 450 c. c.
Cotton-wool filter, heavy screen above.
Wire spring to compress materials.
Small open space at top.

The degree of protection given by a fireman's canister during its useful life is equal to that given by the universal, but as the latter contains a larger quantity of materials it has more capacity and

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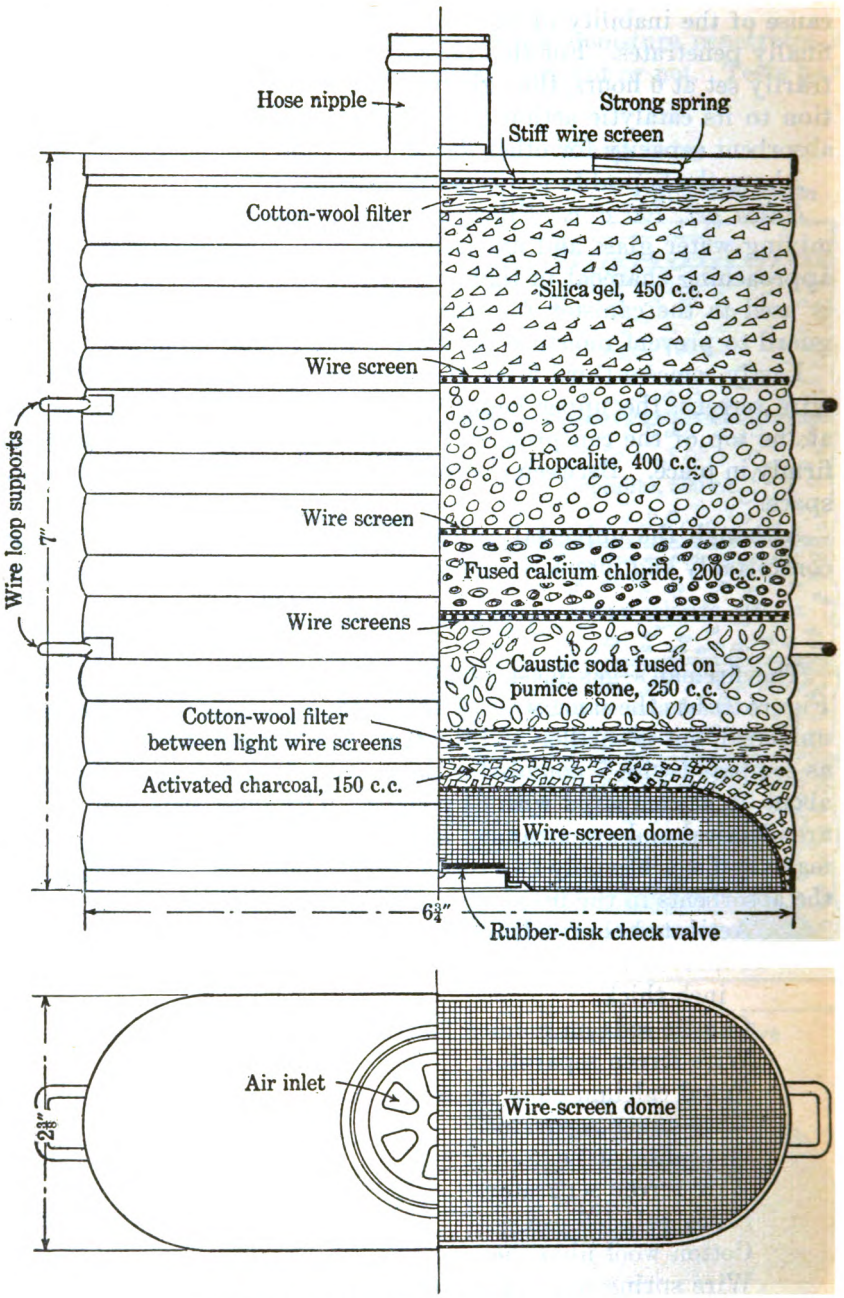

FIGURE 2.—Details of the fireman's canister.

absorbs more gases before failure. Against carbon monoxide the life of the fireman's canister has been set at four hours, allowing a large factor of safety.

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TESTS OF THE MASKS.

Canisters were tested on machines or testing apparatus of the kind developed for testing Army gas-mask canisters;[3] other tests were made by actual wearing in various gases.

MACHINE TESTS.

Figure 3 presents graphically some results of testing universal and fireman's canisters on machines against different gases until failure. Percentage efficiency, shown by the ordinates, gives the proportion of the entering gas or vapor retained by the canister; the duration of the test or "life" of the canister is represented by abscissas.

Against carbon tetrachloride at a concentration of 5,000 volumes per million volumes of air and a flow of 32 liters per minute, equivalent to the breathing of a man doing hard work, the universal canister

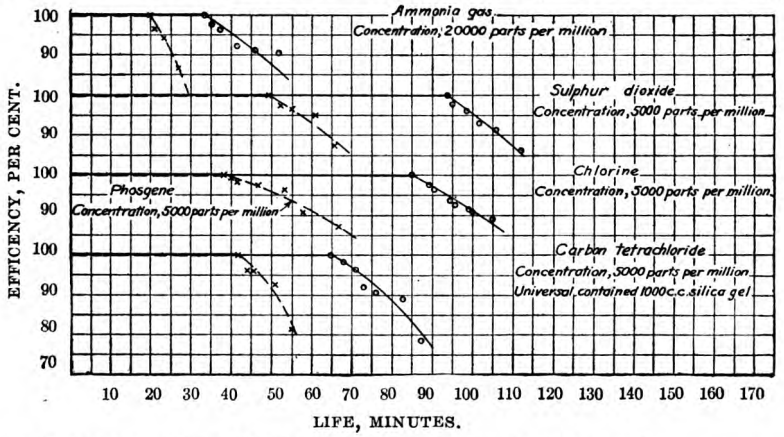

FIGURE 3.—Graphs showing the life of canisters against various gases, o————————o universal canister, x— — — — — —x fireman's canister. Rate of flow of air, 32 liters per minute. Relative humidity, 50 per cent. Temperature, room temperature (about 70° F.).

lasted 65 minutes before the vapor penetrated; the fireman's canister in a similar test lasted 42 minutes. The curves show that penetration is gradual after the break, nearly all the vapor still being retained by the canister. Hence, when a mask is being worn and gas is detected, some time remains for a wearer to escape from a poisonous atmosphere before the quantity penetrating reaches proportions that may do injury.

Against chlorine at a concentration of 5,000 parts per million the universal canister lasted 85 minutes; against phosgene, a gas similar to chlorine as regards absorption by the canister filling, the fireman's canister lasted 38 minutes. Sulphur dioxide (concentration 5,000 parts per million) was retained for 94 minutes by the universal and 49 minutes by the fireman's canister. Ammonia (concentration

[3] Fieldner, A. C., Oberfell, G. G., Teague, M. C., and Lawrence, J. N., Methods of testing gas masks and absorbents: Jour. Ind. and Eng. Chem., vol. 11, June, 1919, pp. 519–540.

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20,000 parts per million, or 2 per cent) penetrated at 33 and 20 minutes, respectively.

Such concentrations of gases as were used in the above tests are seldom encountered, except in chemical apparatus, or when large quantities of gases are liberated in tightly closed rooms, and if they are encountered the duration of the high concentration is usually short. Also the rate of 32 liters per minute corresponds to the breathing of a man doing vigorous work and would not be sustained for so long a time. For these reasons a canister in actual service usually lasts for many hours, and often many days, before it becomes saturated with the gases.

The absorbents for organic vapors, acid gases, and ammonia deteriorate very little when the canisters are worn in atmospheres free from those gases, but protection against carbon monoxide is impaired much more quickly. No effective absorbent for this gas—one that will remove it from air as organic vapors or acid gases are removed—has been found after prolonged search. Hence hopcalite was developed as a catalyzer to oxidize the poisonous monoxide to the relatively harmless dioxide. The hopcalite is effective only while dry, necessitating removal of all water vapor from the air that finally reaches it. Both the caustic pumice and calcium chloride extract water vapor from air, but as air always carries some water vapor, the proportion ranging from about 0.25 to 5 per cent according to temperature and humidity, the action of canisters against carbon monoxide is inhibited after a while, regardless of whether the air passing through has or has not contained carbon monoxide.

Moreover, low temperatures decrease the activity of the hopcalite catalyzer and increase its sensitivity to traces of moisture; hopcalite is active at freezing temperatures or lower, but its useful life is much shorter. For these reasons the Bureau of Mines recommends that in cool or cold weather canisters for protection against carbon monoxide be worn under a coat and thus kept warm by the body.

Figure 4 gives the results of machine tests of universal and fireman's canisters against 10,000 parts per million, or 1 per cent, of carbon monoxide in air; the relative humidity was 50 per cent and the temperature that for a normal room, about 70° F. Figure 5 gives results of similar tests in which the canisters were kept at freezing temperature by submersion in a bath of water and chopped ice; the entering air was chilled by passing through a coil of pipe in the bath. During the tests a canary was placed in a glass jar, containing a perch, through which a stream of air from the canister passed. Tests were continued until the bird, which is more sensitive to carbon monoxide than man, fell from its perch. Temperatures of the outgoing gas were taken at a point distant from the canister equal to the face-mask distance. The oxidation

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of carbon monoxide generates a quantity of heat, depending on its concentration, so that in 2 or 3 per cent the hot air from a canister

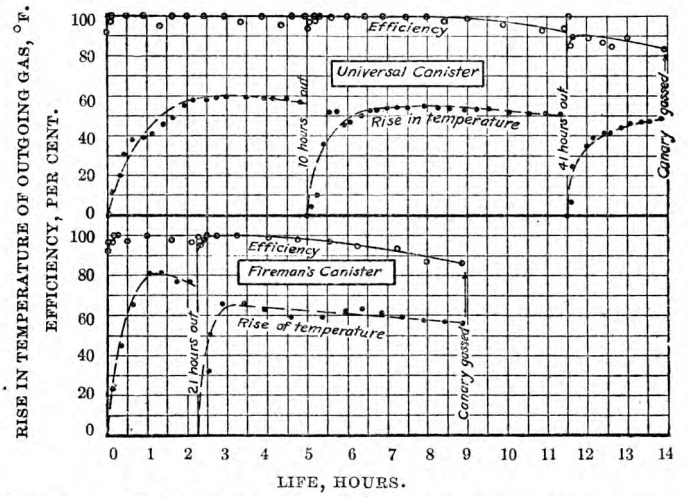

FIGURE 4.—Graphs showing the life of canisters against carbon monoxide at room temperature, about 70° F. Concentration of CO in air, 1 per cent by volume. Rate of flow, 32 liters per minute. Relative humidity, 50 per cent.

after a few minutes becomes almost unbearable to breathe. Hopcalite is exceedingly active against the high concentrations, and the excessive heating of the air gives warning of their presence.

Figures 4 and 5 show a slight lag or pick-up during the first few minutes of use against carbon monoxide. Then in air of normal temperature the efficiency continues at 100 per cent for about 8 hours for the universal canister and 4 hours for the fireman's. In the test with the universal mask a canary dropped from its perch after about 14 hours; in the test with the fireman's mask after about 9 hours. The maximum temperatures of outgoing air were 60° and 80° F., respectively; the higher temperature for the fireman's mask is due to the smaller quantity of materials and hence the smaller capacity to absorb and radiate heat.

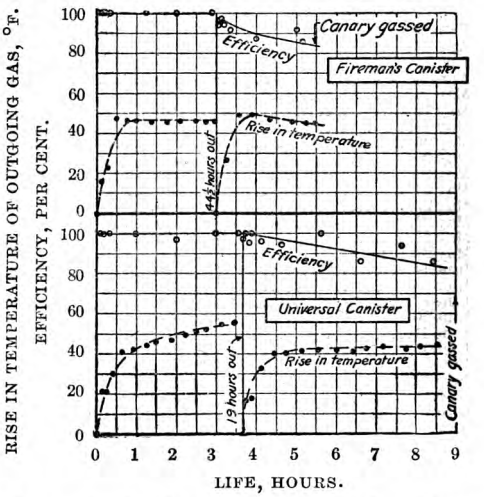

FIGURE 5.—Graphs showing the life of canisters against carbon monoxide at freezing temperature, 32° F. Concentration of CO in air, 1 per cent by volume. Rate of flow, 32 liters per minute. Relative humidity, 100 per cent.

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A fireman's canister tested at the temperature of ice water (32° F.) remained 100 per cent efficient for about 3 hours, as indicated in Figure 5; the canary was gassed in about 5½ hours. Under the same conditions a universal canister maintained its full efficiency for 3¾ hours, and the canary succumbed in 9 hours.

Figure 6 gives the results of testing a universal canister against chlorine, sulphur dioxide, ammonia, and carbon tetrachloride for a total of 55 minutes, and then against carbon monoxide. The life against the last was the same as though it had been used from the start. As the canister contained no calcium chloride, its life against carbon monoxide was considerably shortened. The hopcalite was from a lot made nearly three years before, but the indications are that aging caused little or no deterioration.

TESTS ON MEN.

A universal canister gave service for a period of six months as recorded below; probably a few instances were not recorded:

Service test of a universal canister.

[Canister made Feb. 11, 1921.]

Date.	Gas.	Concentration, per cent in air.	Time of usage, minutes.
1921.			
Feb. 15	Carbon monoxide	1.14	30
Apr. 26	do	.22	60
Apr. 27	do	.46	26
Apr. 28	do	.36	78
May 12	do	.47	63
May 12	do	.40	45
May 14	do	.45	39
May 25	do	.64	30
May 25	do	.53	55
May 26	do	.63	25
May 26	do	.58	25
May 27	do	.52	25
May 27	do	.47	25
May 28	do	.52	26
May 28	do	.46	30
June 14	do	.63	23
June 15	do	.61	20
June 17	do	.58	27
June 20	do	.64	24
June 21	do	.65	24
June 25	do	.66	23
July 5	Wood smoke	Very dense	23
July 6	Ammonia	1 and 2	17
July 7	Formaldehyde	0.25	14
July 7	Sulphur dioxide	½, 1, and 2	15
July 8	Carbon monoxide	1.07	39

Total time in carbon monoxide..... 12 hours 42 minutes.
Total time in all gases..... 13 hours 51 minutes.

During most of its use in carbon monoxide the canister was worn by a physician experimenting with dogs for the purpose of developing better methods of resuscitation. All the experiments were carried to the point where the dog's breathing was suspended, but the man wearing the mask had complete protection. In one experiment, when failure of the canister was suspected, a blood test showed no carbon monoxide breathed by the wearer. No especial care was given

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the mask; during the 5 months it remained in the laboratory atmosphere without protection from outside influences. After use for nearly 14 hours, distributed over the 5-month period, the canister was still effective against carbon monoxide, and its effectiveness against other gases had hardly been touched.

As the universal gas mask uses dry absorbents and delivers dry air its eyepieces are kept free of fog. Such unimpaired vision is of decided advantage compared to the service obtained from gas masks delivering moist air. In both the universal and the fireman's masks the resistance to breathing is low, ranging between 2¼ and 3 inches of water, as compared to 3½ to 4 inches for the Army-type mask. In consequence, breathing requires much less effort, a feature especially noticeable when the wearer does hard work.

Fireman's canisters have been used in various gases, but not for such long periods as the universal. The record of one mask is as follows:

Service test of a fireman's mask.

[Canister made May 5, 1921.]

Date.	Gas.	Concentration, per cent in air.	Time of usage, minutes.
1921.			
May 25	Carbon monoxide	1.00	30
July 5	Wood smoke	Very dense	29
July 6	Ammonia	1 and 2	11
July 7	Formaldehyde	0.25	14
July 7	Sulphur dioxide	½, 1, and 2	25
Total usage			1 hour 49 minutes.

The canister is still good.

These tests show the wide variety of usage for gas masks of the fireman's and the universal type. However, should a workman need protection from a single gas or class of gases, as would a man employed in a refrigerating plant where only ammonia is to be encountered, longer life of canisters at less cost may be had by using a canister filled with an ammonia absorbent; the same considerations hold for men employed around blast furnaces, who have to encounter only carbon monoxide. Similar conditions prevail in many industries, but in some metallurgical and chemical plants workmen may encounter a variety of gases and city firemen may meet almost any type of gas or vapor. Men using the universal type of

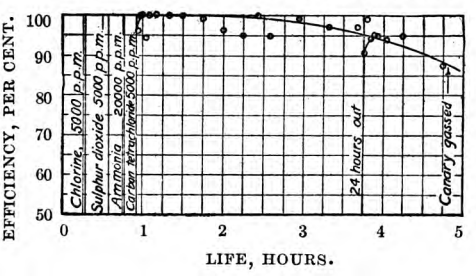

FIGURE 6.—Graph from test of a universal canister (no calcium chloride) against chlorine, sulphur dioxide, ammonia, carbon tetrachloride, and carbon monoxide. Rate of flow, 32 liters per minute. Relative humidity, 50 per cent. Temperature, room temperature.

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mask can face these conditions and do work that they could not do otherwise, except perhaps at the risk of death or serious disability.

LIMITATIONS OF UNIVERSAL GAS MASKS.

The universal gas mask has the widest application of any gas mask thus far developed, and fills every demand that may reasonably be made on a gas mask. Improvements may possibly come in the direction of lengthening the life of absorbents, thus insuring from canisters of the present size longer service or the same service from smaller and lighter canisters; moreover, a carbon monoxide catalyzer unaffected by moisture may be developed so that the life of canisters will be determined entirely by their capacity for other gases.

But there are gases and atmospheres against which neither the universal nor any other gas mask gives protection. Such atmospheres are tabulated below:

Atmospheres or gases against which the universal canister gives no protection.

Gas or atmosphere.	Where found.	Remarks.
Methane.	May be found wherever natural gas is produced or used; also in coal mines.	No adequate absorbent or catalyst known. Methane is harmless in itself, but may make an atmosphere suffocating by reducing the oxygen content below 13 per cent.
Atmospheres deficient in oxygen.	Flues, apparatus in industrial plants, mines, and closed rooms after fires and explosions.	Regardless of its content of poisonous gas, the atmosphere about the wearer of a gas mask must contain enough oxygen to support the flame of a safety lamp to insure against suffocation. For entering an atmosphere deficient in oxygen use either self-contained oxygen breathing apparatus or a mask supplied with pure air through a long hose.
Atmospheres containing higher concentrations of toxic gases.	Chemical or metallurgical apparatus tanks containing gasoline or other volatile liquids; inadequately ventilated rooms in which large quantities of gas are evolved.	Gas masks are for removing from air toxic gases in comparatively low concentrations, such as those found in the open air or in well-ventilated rooms. Tanks holding very volatile liquids, such as gasoline, are especially liable to contain atmospheres high in vapor and low in oxygen. In general, unless the activity and capacity of the canister are known, a mask should not be used in toxic gases having a concentration more than 1 or 2 per cent.

The table above applies to the universal mask. As special types of masks are made that are useful only against a single gas or group of gases, a man should know the purpose and the capacity of a gas mask before he intrusts himself to it in a dangerous atmosphere.

Because of the risk of encountering atmospheres deficient in oxygen in mines after explosions, the Bureau of Mines does not recommend the use of gas masks therein.

Because the wearer of a mask can not tell when carbon monoxide penetrates the canister, a time limit of use is put upon the canisters. The expiration of usefulness may be indicated by a mechanical device

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such as an anemometer, through which the air passes and indicates volume on a dial, or a record of the total time a canister is used may be recorded on a card attached to it, as follows:

Canister record.

[Canister must be discarded after 240 minutes' use.]

Date attached 1-10-21.

Date used	*1/21*	*1/26*			
Time started	*10.36*	*1.21*			
Time ended	*11.20*	*3.02*			
Minutes used	*44*	*101*			
Total minutes used	*44*	*145*			
Remarks	*Ammonia.*	*Wood smoke.*			
(Signature)	*J. Doe*	*R. Roe*			

The card should be filled out after each use and before the mask is put away and the canister should be detached from the mask when its hours of use have reached the total permitted. Carelessness in keeping records may cost the life of a later user of the mask.

As moisture causes deterioration of the hopcalite, masks should be kept in a thoroughly dry place.

As has been indicated, gas masks can not be regarded as foolproof. But as a man's life is often intrusted to their action, the care and attention needed are not excessive requirements. In fact, gas masks require comparatively little attention as compared to self-contained oxygen breathing apparatus.

SUMMARY AND CONCLUSIONS.

Army-type gas masks give no protection against the important industrial gases—ammonia and carbon monoxide—although they serve well against other poisonous gases, vapors, and smokes diluted in air. Furthermore, no gas mask can guard the wearer against suffocation in atmospheres deficient in oxygen, because the canisters serve only as filters for removing comparatively small amounts of poisonous gases from air otherwise normal. The univesal gas mask described in this paper has a canister designed to protect the wearer against low concentrations of any poisonous gas in air, including carbon monoxide and ammonia.

The canister contains granular absorbents, consisting of activated charcoal, for removing organic vapors; a filter of cotton wool for removing smokes, dusts, and mists; caustic soda fused on pumice stone for removing acid gases; another cotton-wool filter; fused calcium chloride for extracting water vapor that inhibits action of the next absorbent; "hopcalite," a mixture of oxides of manganese and copper with sometimes silver and cobalt that destroys carbon monoxide; and finally silica gel for absorbing ammonia. At the top a cotton-wool filter under a heavy screen holds the materials in

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place through pressure exerted by a stiff spring. The volume of the absorbents, 2,600 c. c., requires a canister 8¼ by 2¾ by 8⅝ inches high and weighing when filled about 7 pounds. The complete mask and harness weigh about 8½ pounds.

A similar but smaller and lighter canister, called the "fireman's" canister, contains 1,450 c. c. of absorbent, measures 2⅜ by 6¾ by 7 inches high and weighs 4 pounds. The complete fireman's mask weighs about 5½ pounds and is more convenient to wear than the universal, but has a shorter life—4 hours as compared with 6 hours. Both figures allow a large factor of safety.

Tests of the universal gas mask in actual service have totaled 14 hours without signs of failure. However, the arbitrary life of 6 hours has been adopted because of the inability of a wearer to detect penetration of carbon monoxide; penetration of other gases may be detected by taste or smell. A canister fails gradually, so that the wearer has time to escape from a dangerous atmosphere before the concentration of gas breathed becomes hazardous.

Canisters are more active when warm, so in cool or cold weather they should be worn under a coat to receive body heat.

Workers liable to meet only one gas or class of gases will receive longer service from a canister designed for that particular gas only. But men in some chemical and metallurgical industries and city firemen who may encounter many poisonous gases have especial need of the universal type mask that gives respiratory protection in all atmospheres containing enough oxygen to maintain the flame of a safety lamp.

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APPENDIX.

This appendix outlines the standard test requirements for all gas masks used by the Bureau of Mines in its investigations.

STANDARD TEST REQUIREMENTS FOR GAS MASKS.

Gas-mask canisters, or absorbent containers, are subdivided into the following classes or types:

Type A.—For acid gases, such as carbon dioxide, chlorine, formic acid, hydrogen chloride, hydrogen cyanide, hydrogen sulphide, nitrogen peroxide, phosgene, and sulphur dioxide.

Type B.—For organic vapors, such as acetone, alcohol, aniline, benzene, carbon bisulphide, carbon tetrachloride, chloroform, ether, formaldehyde, gasoline and petroleum distillates, toluene, and similar volatile compounds.

Type C.—For ammonia.

Type D.—For carbon monoxide.

Type E.—For dusts, chemical smokes, fumes, and mists, such as tin tetrachloride, silicon tetrachloride, titanium tetrachloride, and sulphur trioxide.

Type F.—For other special individual gases.

Types AB, AC, etc.—For combinations of the preceding types.

Type N.—For combinations to include all the preceding types.

1. COLOR AND MARKINGS.

Distinctive colors and markings to indicate the purpose of each canister or absorbent container are needed for the purpose of safeguarding the wearers. Standard colors are indicated in the table following:

Table of colors to indicate purpose of masks.

Mask type letter.	Chemical properties of gases absorbed.	Distinctive color required.
A	Acid	White.
B	Organic vapor	Black.
C	Ammonia	Green.
D	Carbon monoxide	Blue.
E	Dusts, smokes, mists	White or black stripes.
F	Other special individual gases.	Color to be assigned.
AB	Acid and organic vapors	Yellow.
Special combinations of those above.	Combinations of those above	Combinations of those above, or a special assigned color. When a dust filter is combined with a gas respirator, it is to be indicated by black or white stripes.
N	All of those above	Red. (Stripes to indicate the filter are unnecessary.)

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The canisters, or containers, for the absorbent material shall be either painted completely in these colors or the color shall be made a distinctive part of the canister design. For chemical smokes or fumes, the canisters shall be of a color to indicate the purpose of the absorbent material contained, and shall be striped with a strongly contrasting color, either black or white, to indicate the filters. The stripes may be placed so as to indicate the number and position of the filters.

Type N, also called universal or fireman's canisters, for protection in air against all gases and smokes need have no stripes on the red color.

On the canisters shall be indicated, in bold letters, a statement to show the purpose of the canisters such as:

FOR USE ONLY IN _____
(Name of gas or gases.)

FOR USE ONLY IN _____ and IN DUSTS.
(Name of gas or gases.)

FOR USE ONLY IN _____
(Name of gas or gases and of chemical fume, according to the purpose of the manufacturer.)

FOR USE IN AIR CONTAINING ANY GAS OR SMOKE.

The statement will name the gas or gases, or classes of gases, in which the gas mask is to be used; if a dust or smoke respirator is combined with gas absorbents, the fact should be indicated. For this purpose it is permissible to attach a metal plate bearing the proper inscription in raised or other distinct letters, or to stamp the statement into the metal of the can with a male and female die. The statement may be printed or stenciled with paint, or paper labels may be used. The latter must be attached with a heat-proof cement and varnished to prevent loosening by moisture.

The knapsack or case in which the gas mask is kept must also have the same statement indicated conspicuously in bold letters. The distinctive color or colors may be that of the letters themselves or that of the background, or part of the design, in such fashion that the distinctive colors are prominent. A striped background may be used to indicate a filter. Metal plates or painted or printed stencils may be used on the knapsacks, but paper labels will not be permissible here.

2. MATERIALS.

The gas mask and equipment must be constructed in all its parts of materials suitable for the purpose they must serve. This applies to the fabric, rubber, metal, chemical, and other parts.

3. DESIGN AND CONSTRUCTION.

The excellence of design and mechanical construction, as well as the workmanship, will be considered. This will be done with regard to safety to the wearer, freedom of his movements and his vision, the fit

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of the face and headpieces and the comfort that is afforded under all conditions of use. There will also be considered the ease with which canisters or other parts of necessarily short life may be replaced by fresh parts, and the tightness of the whole apparatus, with a view to insuring the wearer against leaks of unpurified air both before and after such changes are made.

4. FACE-PIECE TEST.

Two men wearing the gas masks will enter a room containing 1 per cent of sulphur dioxide; if necessary, a canister for acid gases will be attached to the mask for this test. Thirty minutes will be spent in work designed to provide observations on the freedom of movement permitted, freedom from leaks, and the comfort allowed the wearer. The time will be divided as follows:

Ten minutes: Walking, turning head, dipping chin.

Five minutes: Calisthenic movements, such as swinging arms, turning body, bending body at hips.

Ten minutes: Sitting at rest, then walking, and easy movements.

Five minutes: Pumping air into gas cylinder of about 1 cubic foot capacity, with a tire pump, to a pressure of 25 pounds.

To meet approval, it will be necessary that no sulphur dioxide come through the mask during the test, and that no undue discomfort be experienced because of the fit or other mechanical features of the gas mask.

5. RESISTANCE TO FLOW OF AIR.

(*a*) Before and after the chemical tests described under section 6, below, the pressure drop of air passing through the canisters at a rate of 85 liters per minute will be determined in inches of water-column height. At no time must the resistance exceed 4 inches of water.

(*b*) The resistance to flow of air of the complete mask and canister, to inspiration and to expiration, will be determined on a mechanical apparatus, the rate being 85 liters per minute continuous flow; the resistance must not exceed 6 inches of water pressure.

6. CANISTER TESTS.

TYPE A, ACID GASES.

Nine canisters or parts containing the absorbent, separated from the face pieces and harness, will be tested on a chemical testing apparatus under these conditions:

(*a*) Number of canisters, 3. Gas used for testing, chlorine. Concentration of chlorine in air, 5,000 parts per million. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

(*b*) Number of canisters, 3. Gas used for testing, hydrogen cyanide. Concentration of hydrogen cyanide in air, 5,000 parts per

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million. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

(*c*) Number of canisters, 3. Gas used in testing, sulphur dioxide. Concentration of sulphur dioxide in air, 5,000 parts per million. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

Tested in this way, the life or service time of each canister must be at least 20 minutes. The end of the life will be the time at which a test shows five parts per million of chlorine, hydrogen cyanide, or sulphur dioxide in the air coming from the canisters.

TYPE B, ORGANIC VAPORS.

Three canisters or parts containing absorbent, separated from the face pieces and harness, will be tested on a chemical apparatus under the following conditions:

Vapor used for testing, carbon tetrachloride. Concentration of carbon tetrachloride in air, 5,000 parts per million. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

Tested in this way, the life or service time of each canister must be at least 20 minutes. The end of the life will be the time at which the air, after passing through the canister and then through a heated tube, shows hydrogen chloride on a Congo-red test paper.

TYPE C, AMMONIA.

Three canisters containing the absorbent, separated from the face pieces and harness, will be tested on a chemical testing apparatus, under the following conditions:

Concentration of ammonia in air, 20,000 parts per million, or 2 per cent by volume. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

Tested in this way, the life or service time must be at least 20 minutes. The end of the life will be the time at which the air, after passing through the canister, contains 100 parts per million, or 0.01 per cent by volume, of ammonia.

TYPE D, CARBON MONOXIDE.

Six canisters or parts containing the absorbent or catalyst, separated from the face piece and harness, will be tested on a chemical testing apparatus under these conditions:

(*a*) Number of canisters, 3. Gas used for testing, carbon monoxide. Concentration of carbon monoxide in air, 10,000 parts per million, or 1 per cent by volume. Humidity, 50 per cent relative humidity. Temperature, room temperature (approximately 25° C.). Rate of flow of gas, 32 liters per minute, continuous flow.

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(*b*) Number of canisters, 3. Gas used for testing, carbon monoxide. Concentration of carbon monoxide in air, 10,000 parts per million, or 1 per cent by volume. Humidity, 100 per cent relative humidity, at 0° C. Temperature, temperature of melting ice, 0° C., secured by immersing the canister in a bath of ice and water. The incoming air will be cooled by passing it through tubes leading through the ice water to the canister. Rate of flow of gas, 32 liters per minute, continuous flow.

Tested in this way the life or service time will be that time at which carbon monoxide penetrates from the beginning of test in total quantity equivalent to 0.05 per cent uniform outflow for one hour. Under conditions (*a*) this life must be at least 4 hours; under condition (*b*), at least 1 hour.

Carbon monoxide canisters must also have a means of showing when the useful life of the canister has ended since the gas is itself odorless and tasteless; this may be done by causing an increase in resistance to breathing as moisture is absorbed, by allowing a definite increase in weight as moisture is taken up, by a mechanical device to measure the amount of air breathed, or other suitable method. Tests of such methods will be arranged to suit the particular case, and special caution labels may be required for these canisters.

TYPE E, SMOKE, DUST, AND MIST FILTERS.

Filters are divided into the two classes following:

Class 1, for highest degree of protection against very fine particles; class 2, for adequate protection against ordinary smoke from combustibles and against suspensions of coarse particles, such as are produced from tin tetrachloride, and the obtaining at the same time of lower breathing resistance. The test requirements are:

Class 1.—Three filters, separated from the face piece and harness, will be tested on a smoke-testing apparatus under these conditions:

Fume used: Tobacco smoke.

Rate of flow of gas: Eighty-five liters per minute.

Length of test: Five minutes.

Tested in this way the filter must retain at least 95 per cent of the passing tobacco smoke at the end of the 5-minute period.

Class 2.—Six filters, separated from the face piece and harness, will be tested on a smoke-testing apparatus and by man tests as follows:

(*a*) Tobacco-smoke test: Number of canisters, 2. Rate of flow of gas, 85 liters per minute. Length of test, 5 minutes.

Tested in this way the filters must retain at least 50 per cent of the passing tobacco smoke at the end of the 5-minute period.

(*b*) Cotton-smoke man test: Number of canisters tested, 2. Nature of test: Two men will wear the masks into a room of about 1,000 cubic feet capacity filled with the smoke from the smudge burning of 1 pound of cotton waste. If the masks are not made with attached

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canisters for the absorption of gases, such canisters shall have been attached to the filters. The men will remain 10 minutes in the room if the canisters fulfill the following requirements:

No discomforting irritation of the respiratory system or eyes to be experienced by either man; this requirement is necessary for approval.

(*c*) Tin tetrachloride man test: Number of canisters, 2.

Nature of test: Two men stationed outside of a chamber of about 1,000 cubic feet capacity, in which is an atmosphere containing 500 parts per million by volume of tin tetrachloride fumes, will breathe the atmosphere from the chamber through the canisters or filters. If necessary a canister for absorbing acid gases will be attached to the filters. The men will continue the test for 20 minutes if the filters fulfill the following requirement:

No discomforting irritation to be experienced by either man; this requirement is necessary for approval.

TYPE F, OTHER SPECIAL INDIVIDUAL GASES.

Similar tests will be performed on other special gases and will be arranged as the need arises.

TYPES AB, AC, ETC., SPECIAL COMBINATIONS FOR DIFFERENT TYPES OF GASES, AS ABOVE.

Canisters may be tested according to two or more methods, under types A, B, C, D, and E, to secure approval for different gases classed under the different types.

To meet approval it will be necessary that the life for gases in each type or class be equal to the separate requirements.

TYPE N, FOR PROTECTION IN AIR AGAINST ALL GASES, VAPORS, AND SMOKES.

Canisters are divided into two classes. Class 1, or universal canisters, are for protection in air against all substances included in the preceding classes, and in the same degree. Class 2, or fireman's canisters, are for protection against all substances in preceding classes, but the service time requirements are in most instances half those for class 1, which allows a smaller and lighter canister. The test requirements are:

Class 1.—Canisters will be tested as described under types A, B, C, D, and E, class 1, or E, class 2.

To meet approval it will be necessary that the life for gases in each type or class be equal to the separate requirements.

Class 2.—Canisters will be tested as described under types A, B, C, D, and E, class 2.

To meet approval it will be necessary that the life or service time in tests be as follows:

Tests for type A, B, and C—10 minutes.

Tests for type D—4 hours under condition (*a*) and 1 hour under condition (*b*).

Tests for type E—requirements of class 2.

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7. CHEMICAL STABILITY.

To determine the chemical stability under extreme conditions of dryness and moisture, two canisters will be subjected to each of the following tests for which approval is desired:

(*a*) Air free of carbon dioxide, at room temperature and 25 per cent relative humidity, will be passed through each canister, at a rate of 64 liters per minute, for a period totaling 6 hours. The canisters will then be tested, as described under section 6, against gases, as follows:

Approval for acid gas: Chlorine.
Approval for organic vapor: Carbon tetrachloride.
Approval for ammonia: Ammonia.
Approval for carbon monoxide: No test.
Approval for special gas: Special gas to be arranged.
Approval for dusts and mists: No test.
Approval for combinations: Any two or more of the above.

To meet approval, the life of the canister must not fall below 10 minutes in any test. The tests may be omitted for canisters designed for carbon monoxide as one of a combination.

(*b*) Air free of carbon dioxide, at room temperature and 85 per cent relative humidity, will be passed through each of two canisters at a rate of 64 liters per minute, for a period totaling 6 hours, and the canisters will then be tested as described in (*a*) above.

To meet approval, the life of the canisters must not fall below 10 minutes in any test.

8. HIGH RATES OF BREATHING AND MAXIMUM CONCENTRATION.

To insure protection to the wearer at high rates of breathing in gas of high concentration, a stream of air containing 1 per cent of gas and flowing at a rate of 64 liters per minute will be passed continuously through a canister. The other conditions of the tests will be these:

Humidity: Fifty per cent relative humidity.
Temperature: Room temperature (approximately 25° C.).
Gas used in testing—
  Approval for acid gas: Phosgene.
  Approval for organic vapors: Carbon tetrachloride.
  Approval for special gas: Ammonia, carbon monoxide, or other special gas.
  Approval for dusts and mists: No test.
  Approval for combinations: Any two or more of the above.
Concentration: 10,000 parts per million, or 1 per cent by volume, for any gas.
Number of canisters: Two, tested against any gas.

To meet approval the life of the canisters under any of the above tests against gas must be at least 5 minutes, except for carbon monoxide, which must be at least 15 minutes.

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APPROVAL FOR HIGHER CONCENTRATIONS.

It is required that a gas mask pass the tests outlined in the preceding paragraphs in order to obtain approval for use in concentrations of 1 per cent of gas, which is the minimum. To obtain approval for higher concentrations, the canister must pass tests similar in every way to those that have been described, except that the concentration is increased in test 8 in steps of 1 per cent, as far as practicable, and these tests are made on each gas for which approval in higher concentrations than 1 per cent is desired. Approval may be extended for use of the gas masks in the maximum concentration for which they successfully pass the test, except for carbon monoxide, which will be limited to concentrations not exceeding 3 per cent.

CHANGING OF DETAIL OF TESTS.

If the mechanical or other features of a gas mask render it advisable to omit any of the tests or part of a test previously described, or to perform accessory tests, modifications of the test may be made in such manner as to obtain substantially the same information and degree of safety as is provided by the tests described.

PUBLICATIONS ON GAS MASKS AND BREATHING APPARATUS.

A limited supply of the following publications of the Bureau of Mines is available for distribution. Requests for all publications can not be granted. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only by purchase from the Superintendent of Documents, Government Printing Office. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

TECHNICAL PAPER 82. Oxygen mine rescue-apparatus and physiological effects on users, by Yandell Henderson and J. W. Paul. 1917. 102 pp., 5 pls., 6. figs.

TECHNICAL PAPER 248. Gas masks for gases met in fighting fires, by A. C. Fieldner, S. H. Katz, and S. P. Kinney. 1921. 61 pp., 9 pls., 5 figs.

TECHNICAL PAPER 292. Tests of gas-masks and respirators for protection from locomotive smoke in railroad tunnels, with analyses of tunnel atmospheres, by A. C. Fieldner, S. H. Katz, and S. P. Kinney. 1922. 27 pp., 3 pls., 3 figs.

MINER'S CIRCULAR 4. The use and care of mine rescue breathing-apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

BULLETIN 82. International conference of mine experiment stations, Pittsburgh, Pa., September 14–21, 1912, compiled by G. S. Rice. 1914. 99 pp., 4 figs. 15 cents.

TECHNICAL PAPER 77. Report of the committee on resuscitation from mine gases, by W. B. Cannon, G. W. Crile, Joseph Erlanger, Yandell Henderson, and S. J. Meltzer. 1914. 36 pp., 4 figs. 5 cents.

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